Printed polymers, patterned paper

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CHAPTER I

GENERAL INTRODUCTION AND OUTLINE OF THE THESIS

1.1) General introduction

I recently visited a microfluidics lecture in which a renowned scientist from the audience cheerfully announced that the research that was being presented that day reminded him of his son's Tamagotchi. One's first reaction is to feel offended by this abominable oversimplification. Here we are, trying to contribute to the healthcare technology of the 21st Century, giving our very best to face contemporary global issues, and our efforts are summarized by the phrase: "It reminds me of my son's Tamagotchi." Yet later, after recounting these events to colleagues who had not attended, and after some quiet contemplation, I had an epiphany of sorts. I suddenly came to understand that a (microfluidics) scientist should be proud to have his or her work compared to a Tamagotchi for no less than three reasons.

First of all, the Tamagotchi is incredibly easy to use. The interface tells you in a very understandable and relatable way what sort of action is required from the user. These actions and their execution are very intuitive. You immediately get feedback from the device on whatever it was you just did. Furthermore, if you did it well, it gives you a feeling of reward, which motivates you to diligently continue to perform your tasks. Finally, all of this is made possible by technology that most of its users do not understand and certainly cannot reproduce, a fact which is well hidden beneath the happy interface.

Secondly, it is a product which reached immense popularity. Tamagotchi was and still is used by children (and adults) over the globe and probably earned its developers a vast amount of money. The handheld pet was well thought of, well marketed and therefore well sold. An important reason for success in society is that there has to be an *actual need* for a product, rather than the *assumed need*, that we generally present in our justification slides. In the case of the Tamagotchi, the need is easy to understand. A kid wants a pet (because it is cute), and Mum and Dad do not (allergy, additional work, additional costs, the mess, the smell). Tamogotchi satisfies everyone, or at least represents a good compromise.

Finally, the Tamagotchi is a typical example of conceptual innovation. Both success and controversy made this product a phenomenon. This is a product that only simulates life and feelings, yet still manages to trigger an emotional response in human beings. The novelty was not found in the electronics or the programming, and it was not found in the graphics, which were far from spectacular. Rather, the novelty lies in the use of these basic tools to realize a concept that others had never thought of before.

Thus, by comparing one's work to a Tamagotchi, you are essentially saying that you believe it to be conceptually innovative with great societal/market potential, which might be based on generally unintelligible technology, yet still is accessible to its end-users. These qualities are exactly what we tried to achieve for the analytical devices presented in this thesis.

All the work in this thesis is based on either paper, 3D-printed polymers, or a combination of both. These are inexpensive materials and thus a good starting point for our mission. Both classes of materials have distinct characteristics and advantages that make them so suitable, as will be elaborated in detail in this thesis. We are not the first to ever work with these materials in the field of microfluidics. Like the inventors of the Tamagotchi, we strive to create innovative concepts by employing already existing tools, and in doing so we are pushing the boundaries of functionalizing portable analytics. Availability, Affordability, and user-friendliness and keywords for not only the work, but even more so for the possible applicability of the work to society.

1.2) Outline of the thesis

The first part of this thesis provides the reader with a more detailed background of paper-based analytical tests (Chapter 2) and fused deposition modeling (FDM) 3D printing (Chapter 3). The second part of the thesis describes the development of a 3D-printed cartridge for paper spray ionization, which integrates features for control over solvent flows (Chapter 4) and ion optics and sheath gas release (Chapter 5). The third part of the thesis revolves around our forays into the field of paper microfluidics. We demonstrate that we can functionalize paper devices by integration of solvent selective valves (Chapter 6), two-phase counter flow (Chapter 7), and on-paper concentration of sample (Chapter 8). We then introduce mass spectrometric detection to paper microfluidics by combining hydrophobic patterning with paper spray ionization (Chapter 9). Finally, we give a number of general conclusions based on this work (Chapter 10) and summarize the thesis.

PART I

TOOLS FOR INEXPENSIVE ON-SITE ANALYSIS